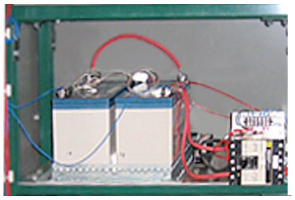
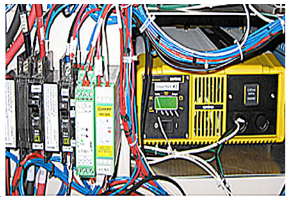
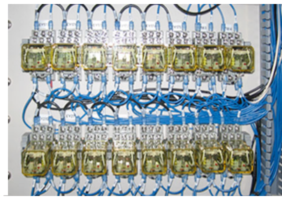





ADAPT
Advanced Diagnostics and Prognostics Testbed

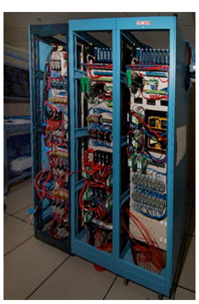
Purpose

The Advanced Diagnostics and Prognostics Testbed (ADAPT) at the NASA Ames Research Center is a unique facility designed to test, measure, evaluate, and mature diagnostic and prognostic health management technologies. The testbed has three main goals: to 1) assess performance of diagnostic tools and algorithms against a standardized testbed and repeatable failure scenarios, 2) develop prognostic models (performance degradation, remaining life estimation) for spacecraft subsystems such as the Electrical Power System (EPS) and Communications, and 3) prototype Advanced Caution and Warning System (ACAWS) algorithms and user interfaces, to characterize which technologies are most appropriate for various faults and contexts.

Background

As humans venture farther out of low earth orbit, communications delays make it necessary to migrate health management for a vehicle or habitat to the crewed system itself. Real-time health management promises improved affordability, reliability, and effectiveness for other complex engineering systems as well. However, it has its own costs in terms of development, power, weight, size, communications, training, and maintenance. New vehicle programs must decide what monitoring and intervention technologies will maximize their return on investment, given mission requirements that balance risk, reliability, and cost.

Capabilities



The initial testbed is functionally representative of an exploration vehicle's Electrical Power System (EPS). It includes three sets of 100 amp-hr sealed lead acid batteries, battery chargers, a solar panel unit with charge-control regulator, and a controller for power generation, storage, distribution, and monitoring. Data acquisition and control functions are provided by two National Instruments Compact FieldPoint backplanes. Electromechanical and solid-state relays carry power to two load banks, each with two 24 VDC outlets and six 120 VAC outlets. Sensors report temperature, current, voltage, relay-position, and light-sensor measurements.

The system supports nominal and failure operations of the EPS, for standardized fault configurations or for spontaneous (but repeatable) insertions during system demonstrations. In a typical EPS test, an *antagonist* inserts single or multiple faults into the hardware or software configuration, either manually, remotely, or through software scripts. A *user*—simulating a crew member—must detect, characterize, and respond to the problem. An *observer* at a third console monitors the trial and logs real-time data for analysis or retesting.

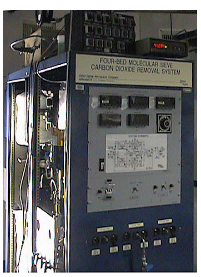
Multi-screen LabVIEW displays—customized for these roles—show the observable or true status and behavior of EPS voltages, currents, and components. Implemented faults include tripped circuit breakers, failed relays (open, closed, or overheating), failed sensors (shorted, open, or stuck), failed AC inverters, and blocked solar arrays. Other faults could include calibration problems, sensor noise, broken wires, failed battery or photovoltaic chargers, overheated or overcharged batteries, and faults in loads.

HyDE Application

The primary articles under test are the health management applications, not the physical devices of the testbed. The application currently deployed is the Hybrid Diagnostic Engine (HyDE), developed at NASA Ames. It provides online mode tracking, fault detection, and fault isolation to the component level. HyDE itself is a general inference engine, adapted to specific systems by loading a model of the system.

In future efforts, other health management applications from industry, academia, and government will be integrated and tested. These techniques may be model-based or data-driven, and may address fault detection, isolation, and recovery (FDIR), prognostics, variable autonomy, or data fusion and diagnostic fusion. Testbed software will evaluate fault detection and isolation times, false and missed alarm rates, precision of fault isolation, and other statistics.

Future Plans



Future builds will include spacecraft subsystems such as Guidance, Navigation, and Control (GNC) and an Environmental Control and Life Support System (ECLSS). Within the EPS simulation, the testbed may add Li-ion batteries, fuel cells, and DC-to-DC power converters, with corresponding fault modes. ADAPT may also connect to other testbeds through the Internet, to provide a more complete vehicle simulation or a more thorough analysis of human-machine interaction. In particular, ADAPT will interface with the Intelligent Spacecraft Interface Systems (ISIS) and Mission Control Technologies laboratories at Ames, to help refine customer's requirements for integration of health management into mission operations.

Additional health management applications will also be implemented in a software architecture able to support pre-launch checkout, launch, flight, re-entry, and post-flight checkout. Reasoning methods will also be expanded to prognostic modeling of component performance degradation and remaining life. A baseline of Figures of Merit (FOM) and Technical Performance Metrics (TPM) will be developed to assess the effectiveness of the health management technologies. It is anticipated that these technologies will exhibit different strengths and weaknesses that will need to be considered when constructing a health management solution for a particular system. By characterizing their capabilities, valuable information will be available to system designers performing trade studies for actual missions.